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FORM PTO-1390 (Modified) (REV 10-95) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: **9847-0009-6X PCT**

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR): **09/297570**

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/SE97/01844	**NOVEMBER 4, 1997**	**NOVEMBER 4, 1996**

TITLE OF INVENTION

DEVICE FOR CONTROLLING FAULT CURRENTS IN A ROTATING ELECTRIC MACHINE

APPLICANT(S) FOR DO/EO/US

Jan -Anders NYGREN, et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 18 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
    A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☐ Certificate of Mailing by Express Mail
19. ☒ Other items or information:

Request for Consideration of Documents Cited in International Search Report
Notice of Priority
Clean Copy of the Specification Incorporating the Amendments Requested by Preliminary Amendment (pages 1-8)

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
	PCT/SE97/01844	9847-0009-6X PCT

20. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS PTO USE ONLY
☐	Search Report has been prepared by the EPO or JPO	**$840.00**
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482)	**$670.00**
☐	No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))	**$760.00**
☒	Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO	**$970.00**
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)	**$96.00**

ENTER APPROPRIATE BASIC FEE AMOUNT =	**$970.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	14 - 20 =	0	x $18.00	**$0.00**	
Independent claims	2 - 3 =	0	x $78.00	**$0.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS			=	**$1,100.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**.			☐	**$0.00**	
SUBTOTAL			=	**$1,100.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).			+	**$0.00**	
TOTAL NATIONAL FEE			=	**$1,100.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**			☐	**$0.00**	
TOTAL FEES ENCLOSED			=	**$1,100.00**	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$1,100.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees.
A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **15-0030** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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WILLIAM E. BEAUMONT
REGISTRATION NUMBER 30,996

SIGNATURE

Gregory J. Maier
NAME

25,599
REGISTRATION NUMBER

July 4, 1999
DATE

8090
9847-0009-6X PCT

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF: :

JAN-ANDERS NYGREN ET AL : ATTN: NEW APPLICATION DIVISION

SERIAL NO: NEW US PCT APPLICATION
(based on PCT/SE97/01844)

FILED: HEREWITH :

FOR: DEVICE FOR CONTROLLING :
FAULT CURRENTS IN A
ROTATING ELECTRIC MACHINE

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Prior to examination on the merits, please amend the above-identified application as follows:

IN THE SPECIFICATION

Please amend the specification as follows:

Page 1, line 1, delete in its entirety and insert therefor:

--8090

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TITLE OF THE INVENTION--;

line 2, change the existing title to read as follows:

--DEVICE FOR CONTROLLING FAULT CURRENTS IN A ROTATING ELECTRIC MACHINE--;

before line 3, insert

--BACKGROUND OF THE INVENTION

Field of the Invention--;

prenumbered line 3, change "the" (second occurrence) to --an--;

prenumbered line 4, change "the" to --an--;

prenumbered line 12, change "uses" to --use--;

before prenumbered line 23, insert

--Discussion of the Background--;

prenumbered line 27, before "that" insert --the fact--;

prenumbered line 33, after "machines" insert --(i.e., without the intermediate transformer)--.

Page 2, before line 3, insert

--SUMMARY OF THE INVENTION--;

prenumbered line 8, change ".." to --.--;

prenumbered line 17, delete "a".

Page 3, prenumbered line 25, change "said" to --the--;

prenumbered line 27, delete "hereby".

Page 4, before prenumbered line 6, insert

--BRIEF DESCRIPTION OF THE DRAWINGS--;

prenumbered line 7, change ";" to --:--;

prenumbered line 9, change "shows" to --is a perspective view of--;

prenumbered line 10, change "," to --;--;

prenumbered line 13, change "," to --;--;

prenumbered line 16, change "winding ," to --winding,--; same line, change "means" to --way--;

prenumbered line 17, change "," to --;--;

prenumbered line 20, change "." to --;--;

prenumbered line 23, change "," to --;--;

before prenumbered line 29, insert

--DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS--;

prenumbered line 29, change "Figure 1 thus" to --Referring now to the drawings, Figure 1—.

Page 5, line 1, change "the figures" to --Figure 2--;

prenumbered line 6, after "arc in" to --the end winding region--;

prenumbered line 11, change "comprises" to --includes--;

prenumbered line 12, change "in to" to --into--;

prenumbered line 18, change "known from" to --described in a related--;

prenumbered line 19, after "," insert --and having overlapping inventorship with the present invention,--;

prenumbered 23, change "consist of" to --have--.

IN THE CLAIMS

Please cancel without prejudice or disclaimer Claims 1-12.

Please add new Claims 13-26 as follows:

--13. A rotating electric machine for high-voltage operation, comprising :

a stator;

a rotor disposed within said stator;

a set of windings having high-voltage cables that enclose an electric field in the set of windings, said set of windings having an end winding region; and

a fault current control device including,

an elongated member of an electrically conducting material connected to ground and disposed in the end winding region.

14. The rotating electric machine of Claim 13, further comprising:

other elongated members positioned in the end winding region such that a maximum distance between respective of the elongated member and the other elongated members being sufficiently small to deflect to ground an arc originating in the end winding region.

15. The rotating electric machine of Claim 14, wherein:

said elongated member and said other elongated members being inserted a predetermined distance into the end winding region, said predetermined distance being limited such that eddy currents produced in said elongated member and said other elongated members being below a predetermined magnitude.

16. The rotating electric machine of Claim 13, wherein:

said elongated member being slotted so as to reduce eddy-current losses.

17. The rotating electric machine of Claim 13, wherein:

said elongated member including a plurality of small conductors combined into a bundle having a cross-sectional area of sufficient size to deflect short-circuit currents arising in the end winding region during a fault event.

18. The rotating electric machine of Claim 13, further comprising:

a spacer made of resilient, electrically conducting material, said spacer being applied

between said elongated member and another elongated member in the end winding region and positioned to contact respective outer semi-conducting layers of the high-voltage cables.

19. The rotating electric machine of Claim 18, wherein:

said elongated member being inserted into the spacer.

20. The rotating electric machine of Claim 18, further comprising:

other spacers, said elongated member being in contact with said spacer and said other spacers, said spacer and said other spacers being arranged one after another in a direction toward an end of the stator.

21. The rotating electric machine of Claim 13, wherein:

said fault current control device comprising a flexible wire.

22. The rotating electric machine of Claim 13, wherein:

said fault current control device being configured to mechanically stabilize the set of windings in the end winding region.

23. The rotating electric machine of Claim 13, wherein:

each of said high-voltage cables being flexible and having at least one current-carrying conductor disposed within an inner layer of material having semiconducting properties, said inner layer being disposed within a solid insulating part, said solid insulating part being disposed within an outer layer material having semiconducting properties.

24. The rotating electric machine of Claim 13, wherein:

said windings being configured to carry a voltage of at least 36 kV.

25. The rotating electric machine of Claim 24, wherein:

said winding being configured to operate in an inclusive high-voltage range of 400 kV through 800 kV.

26. A rotating electric machine for high-voltage operations, comprising:

a stator;

a rotor disposed in said stator;

a set of windings having high voltage cables enclosing an electric field within the windings; and

means for controlling a fault current and for conducting said fault current to ground in an end winding region of said set of windings.--

IN THE ABSTRACT OF THE DISCLOSURE

After page 8, insert the Abstract from the following page:

--ABSTRACT OF THE DISCLOSURE

A rotating electric machine for high-voltage operation includes a stator, rotor and windings. The windings have high-voltage cables that enclose an electric field. The machine also includes a device for controlling a fault current, where the fault current is conducted to ground at an end winding region by way of an electrically conducting material.--

REMARKS

Favorable consideration of this application, as presently amended and in light of the following discussion, is respectfully requested.

Claims 13-26 are pending, Claims 1-12 having been cancelled without prejudice or disclaimer and Claims 13-26 having been added by way of the present amendment. New Claims 13-26 find support in original Claims 1-12 and in the specification as originally filed, and consequently no new matter is added.

Because numerous amendments have been made to the specification, consistent with U.S. patent drafting practice, each amendment is believed to be made as a matter of form. However, to the extent any amendment to the specification is substantively inconsistent with the originally filed specification, the language included in the originally filed specification should be construed as containing the controlling language. Due to the large number of changes, and for the Examiner's convenience, a "clean copy" of the specification is filed herewith that includes all the amendments made by way of the present Preliminary Amendment. Also filed herewith, for the Examiner's convenience, is an International Preliminary Examination Report.

At the present time, the undersigned are working with Directors of Technology Center 2800, Mr. Stuart Levy and Ms. Janice Howell, in establishing a special procedure for handling Information Disclosure Statements for this case and numerous other related cases. Accordingly, for efficiency purposes, the Examiner is invited to telephone the undersigned to ascertain the present status of this procedure if no such indication is included in the file at the time of examination.

Consequently, in view of the present amendment, an action on the merits is earnestly solicited.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
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THE FOLLOWING IS THE CLEAN COPY OF THE SPECIFICATION INCORPORATING THE AMENDMENTS REQUESTED BY PRELIMINARY AMENDMENT (pages 1-8)

8090
9847-0009-6X PCT

TITLE OF THE INVENTION

DEVICE FOR CONTROLLING FAULT CURRENTS IN A ROTATING ELECTRIC MACHINE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a device for controlling fault currents in an end winding region of a stator in a rotating high-voltage electric machine.

The type of machines under consideration may, for instance, be synchronous machines, asynchronous machines, dual-fed machines, outerpole machines and synchronous flow machines. The machines are in the first place intended to be used as generators in power stations for generating electric power. The machines are intended to be used at high voltages, a typical operating range being voltages from 36 kV up to 800 kV, for instance, so that they can be connected directly to all types of high-voltage power networks. The machines use high-voltage insulated electric conductors for the stator winding, in the following called winding cables, with solid insulation similar to cables for transferring electric power, e.g. XLPE -cables. The cable is also provided with an outer semi-conducting layer with the help of which its outer potential is defined. The high voltage cables thus enclose the electrical field within the windings. Such an insulated conductor or cable is flexible and it is of a kind which is described more in detail in the PCT applications SE97/00874 and SE97/00875. Additional descriptions of the concerned insulated conductor or cable can be found in the PCT applications SE 97/009001, SE 97/00902 and SE97/00903.

Discussion of the Background

In the event of an internal fault, an electric arc may occur in the machine, which normally finds its way from the position of the fault to other cables or to the stator laminations. In high-voltage electric machines designed for connection to high-voltage power networks without intermediate transformers, these fault currents may be very high. This is due to the fact that the contribution of the short circuit power from the power network can be high. In conventional machines of this type according to the state of the art, which have to be connected to a power network via an intermediate transformer, the contribution to

the fault current coming from the network is reduced due to the transformer. However, the short-circuit current contribution from the machine itself may of course be high. In the case of directly connected machines (i.e., without the intermediate transformer) of the type to which the invention relates, the resulting fault currents due to an internal short circuit may be very high. The short-circuit power in this case will be composed of both contributions from the power network and the short-circuit power from the machine itself. It is therefore important that the high fault current which can occur in directly connected high-voltage machines is controlled so that the damage is as slight as possible.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to provide a device in the end winding region, which enables such control of fault currents.

This is achieved by having a device of electrically conducting material connected to ground potential, at the end winding.

By having a device of conducting material in the end winding region, connected to ground, an arc arising in the event of a fault is directed to ground. Thereby the arc does not pass to other cables in the vicinity or to the stator laminations. With a device according to the invention, therefore, an arc occurring in the event of a fault will burn between the position of the fault and ground via this conducting material, thereby minimizing the damage.

In the end winding region of conventional machines, according to prior art, and typically intended for voltages below 30 kV, it is not possible to insert any non insulated conductive material due to the strong electric fields. In the above mentioned high-voltage machine, the electric field in the end winding region is reduced to zero or close to zero, due to the grounded outer semi-conducting layers of the cables constituting the windings, thereby making fault current control possible.

Arcs occurring in the event of a fault are detected by measuring the current or its derivatives in the phases, for instance, by electronics being provided to disconnect the machine if the current becomes too high or/and if the derivative becomes too large. Another type of fault detection is based on comparing incoming and outgoing currents and, if the difference between them is sufficiently great, this is taken as an indication that a fault exists. Arc monitors in the form of optical detectors are also used.

According to a preferred embodiment of the device according to the invention, the

conducting material can be a rod, pipe or the like with a diameter chosen to be as small as possible in order to minimize eddy-current losses, but sufficiently large enough to enable fault currents to be deflected during fault conditions.

According to a second advantageous embodiment of the device according to the invention, the rods or the pipes are placed so close together in the end winding region that electric arcs in the event of an internal fault are safely directed to ground, i.e. an arc occurring in the event of an internal fault is safely caught by the fault-current control device before it finds its way to other cables or the stator lamination.

According to yet another advantageous embodiment of the device according to the invention, the rods or the pipes are inserted a certain distance into the end winding region, this distance being limited so that eddy currents produced in the rods or the pipes are below a predetermined magnitude.

According to still another advantageous embodiment of the device according to the invention, the rods or the pipes are slotted in order to reduce eddy-current losses.

According to yet another advantageous embodiment of the device according to the invention, the rods or the pipes comprise a plurality of rods or pipes of small diameter combined to a bundle having sufficient cross-sectional area to deflect short-circuiting currents arising in the end winding region in the event of a fault.

According to still another advantageous embodiment of the device according to the invention, the rods or the pipes are arranged to be in contact with spacers made of resilient, electrically conducting material, the spacers being applied between adjacent winding cables in the end winding region, in contact with the semiconducting layers of the winding cables. The rods or the pipes may be inserted into the spacers or into lugs provided on the spacers and each rod or pipe may be arranged to be in contact with several spacers arranged one after the other in the direction of the stator end. In this way the cables in the end winding region part are grounded via the fault-current control rods or pipes which are designed to be able to deflect considerable fault currents.

According to yet another advantageous embodiment of the device according to the invention, the rods, pipes or the like are also used to mechanically stabilize the end winding.

With the device according to the invention, an arc due to an internal fault in the end winding region will be directed to ground via a fault-current control device. The damage to the end winding region is thus reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described in more detail by way of examples only, with particular reference to the accompanying drawings in which:

Figure 1 is a perspective view of a part of the stator, partially cut away and with the rotor removed;

Figure 2 shows a part of the end winding region with rods inserted for fault current control;

Figure 3 shows a part of the end winding region seen from "inside" the end winding, with spacers between the cables grounded by way of the fault-current control rods;

Figures 4 and 5 shows a detail of the end winding region in Figure 3 on a larger scale;

Figure 6 shows the arrangement in Figures 4 and 5 grounded through a fault-current control rod; and

Figures 7, 8 and 9 are views corresponding to Figures 4, 5 and 6, respectively, showing an alternative embodiment of the spacers between the cables.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, Figure 1 shows a part of the stator 2 in a rotating high-voltage electric machine. The stator 2 is partially cut away and the rotor removed for greater clarity. The stator winding cables are placed in radial slots 8 in the stator core. The slots 8 extend to the rear section 4 of the stator core.

Figure 2 shows a part of the upper end winding region of the stator as shown in Figure 1 with fault-current control rods inserted between the cables 12 in the end winding region. The fault-current control rods 10 in Figure 12, are inserted from above, ending a certain distance from the lamination upper surface 13.

The rods 10 are grounded and the conductors 14 are designed to connect several rods, at 16 ... 18, to a group of rods 10. The rods 10 are placed so close together in the end winding that an arc in the end winding region is safely directed to ground via the rods 10 and conductor 14 without finding its way to other cables 12 or to the stator lamination, which would otherwise be damaged. The conductor 14 is preferably made of copper or aluminum

Each fault-current control rod 10 suitably includes a plurality of rods of small diameter, e.g. 3 mm, combined into a bundle of rods having sufficient cross-sectional area, e.g. 100 mm^2, to deflect short-circuit currents appearing in the end winding region in the

event of a fault. The eddy-current losses are thus reduced.

Figure 3 shows a part of the end winding region from "inside" the end winding, with spacers 20 arranged between adjacent cables 12. The arrangement of these spacers 20, described in a related patent application entitled "Device at the end winding region in a rotating electric machine", and having overlapping inventorship with the present invention, is shown in more detail in Figures 4 and 5. Adjacent cables 12 are thus clamped together (not shown in detail in the figures) with an intermediate spacer 20 of a resilient, electrically conducting material.

The cables 12 have a conducting core 22, surrounded by a semi-conducting layer 24, a solid insulation 26 and an outer semi-conducting layer 28 in contact with the spacers 20, as can be seen in Figure 4. The outer semi-conducting layers 28 of the cables 12 are thus electrically connected to each other through intermediate spacers 20. A protruding lug 30 with a hole 32 running through it, is provided at the side of the spacers 20. A fault-current control rod 10 is inserted through the hole 32 in the lug 30 and connected to ground via the conductor 14, see Figures 3 and 6. The semi-conducting outer layers 28 of the cables 12 are therefore grounded via spacers 20, fault-current control rods 10 and the ground conductor 14. As can be seen in Figures 3 and 6, each conductor 14 is connected to a plurality of fault-current control rods, illustrated at 16...18 in a group of rods.

Figures 7, 8 and 9 show views corresponding to those in Figures 4, 5 and 6, respectively, of an alternative embodiment of the spacer 34 with an elongated lug or flange 36 which, unlike the lug 30 in Figures 4-6 extends along the entire length of the spacer 34. A hole 38 runs through this flange 36, in which a fault current control rod 10 is inserted via the conductor 14 which combines several fault-current control rods, at 16...18, in to a group of rods, connected to ground.

Claims

13. A rotating electric machine for high-voltage operation, comprising:

a stator;

a rotor disposed within said stator;

a set of windings having high-voltage cables that enclose an electric field in the set of windings, said set of windings having an end winding region; and

a fault current control device including,

an elongated member of an electrically conducting material connected to ground and disposed in the end winding region.

14. The rotating electric machine of Claim 13, further comprising:

other elongated members positioned in the end winding region such that a maximum distance between respective of the elongated member and the other elongated members being sufficiently small to deflect to ground an arc originating in the end winding region.

15. The rotating electric machine of Claim 14, wherein:

said elongated member and said other elongated members being inserted a predetermined distance into the end winding region, said predetermined distance being limited such that eddy currents produced in said elongated member and said other elongated members being below a predetermined magnitude.

16. The rotating electric machine of Claim 13, wherein:

said elongated member being slotted so as to reduce eddy-current losses.

17. The rotating electric machine of Claim 13, wherein:

said elongated member including a plurality of small conductors combined into a bundle having a cross-sectional area of sufficient size to deflect short-circuit currents arising in the end winding region during a fault event.

18. The rotating electric machine of Claim 13, further comprising:

a spacer made of resilient, electrically conducting material, said spacer being applied between said elongated member and another elongated member in the end winding region and positioned to contact respective outer semi-conducting layers of the high-voltage cables.

19. The rotating electric machine of Claim 18, wherein:

said elongated member being inserted into the spacer.

20. The rotating electric machine of Claim 18, further comprising:

other spacers, said elongated member being in contact with said spacer and said other

spacers, said spacer and said other spacers being arranged one after another in a direction toward an end of the stator.

21. The rotating electric machine of Claim 13, wherein:

said fault current control device comprising a flexible wire.

22. The rotating electric machine of Claim 13, wherein:

said fault current control device being configured to mechanically stabilize the set of windings in the end winding region.

23. The rotating electric machine of Claim 13, wherein:

each of said high-voltage cables being flexible and having at least one current-carrying conductor disposed within an inner layer of material having semiconducting properties, said inner layer being disposed within a solid insulating part, said solid insulating part being disposed within an outer layer material having semiconducting properties.

24. The rotating electric machine of Claim 13, wherein:

said windings being configured to carry a voltage of at least 36 kV.

25. The rotating electric machine of Claim 24, wherein:

said winding being configured to operate in an inclusive high-voltage range of 400 kV through 800 kV.

26. A rotating electric machine for high-voltage operations, comprising:

a stator;

a rotor disposed in said stator;

a set of windings having high voltage cables enclosing an electric field within the windings; and

means for controlling a fault current and for conducting said fault current to ground in an end winding region of said set of windings.

DEVICE FOR CONTROLLING FAULT CURRENTS IN A ROTATING ELECTRIC MACHINE

ABSTRACT OF THE DISCLOSURE

A rotating electric machine for high-voltage operation includes a stator, rotor and windings. The windings have high-voltage cables that enclose an electric field. The machine also includes a device for controlling a fault current, where the fault current is conducted to ground at an end winding region by way of an electrically conducting material.

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Device for controlling fault currents in a rotating electric machine

The present invention relates to a device for controlling fault currents in the end winding region of the stator in a rotating high-voltage electric machine.

The type of machines under consideration may, for instance, be synchronous machines, asynchronous machines, dual-fed machines, outerpole machines and synchronous flow machines. The machines are in the first place intended to be used as generators in power stations for generating electric power. The machines are intended to be used at high voltages, a typical operating range being voltages from 36 kV up to 800 kV, for instance, so that they can be connected directly to all types of high-voltage power networks. The machines uses high-voltage insulated electric conductors for the stator winding, in the following called winding cables, with solid insulation similar to cables for transferring electric power, e.g. XLPE - cables. The cable is also provided with an outer semi-conducting layer with the help of which its outer potential is defined. The high voltage cables thus enclose the electrical field within the windings. Such an insulated conductor or cable is flexible and it is of a kind which is described more in detail in the PCT applications SE97/00874 and SE97/00875. Additional descriptions of the concerned insulated conductor or cable can be found in the PCT applications SE 97/009001, SE 97/00902 and SE97/00903.

In the event of an internal fault, an electric arc may occur in the machine, which normally finds its way from the position of the fault to other cables or to the stator laminations. In high-voltage electric machines designed for connection to high-voltage power networks without intermediate transformers, these fault currents may be very high. This is due to that the contribution of the short circuit power from the power network can be high. In conventional machines of this type according to the state of the art, which have to be connected to a power network via an intermediate transformer, the contribution to the fault current coming from the network is reduced due to the transformer. However, the short-circuit current contribution from the machine itself may of course be high. In the case of directly connected machines of the type to which the invention relates, the resulting fault currents due to an internal short circuit may be very high. The short-circuit power in this case will be composed of both contributions from the power network and the short-circuit power from the machine itself. It is therefore important that the

high fault current which can occur in directly connected high-voltage machines is controlled so that the damage is as slight as possible.

The object of the present invention is therefore to provide a device in the end winding region, which enables such control of fault currents.

This is achieved by having a device of electrically conducting material connected to ground potential, at the end winding..

By having a device of conducting material in the end winding region , connected to ground , an arc arising in the event of a fault is directed to ground. Thereby the arc does not pass to other cables in the vicinity or to the stator laminations. With a device according to the invention, therefore, an arc occurring in the event of a fault will burn between the position of the fault and ground via this conducting material, thereby minimizing the damage.

In the end winding region of a conventional machines, according to prior art, and typically intended for voltages below 30 kV, it is not possible to insert any non insulated conductive material due to the strong electric fields. In the above mentioned high-voltage machine, the electric field in the end winding region is reduced to zero or close to zero, due to the grounded outer semi-conducting layers of the cables constituting the windings, thereby making fault current control possible.

Arcs occurring in the event of a fault are detected by measuring the current or its derivatives in the phases, for instance, by electronics being provided to disconnect the machine if the current becomes too high or/and if the derivative becomes too large. Another type of fault detection is based on comparing incoming and outgoing currents and, if the difference between them is sufficiently great, this is taken as an indication that a fault exists. Arc monitors in the form of optical detectors are also used.

According to a preferred embodiment of the device according to the invention, the conducting material can be a rod, pipe or the like with a diameter chosen to be as small as possible in order to minimize eddy-current losses, but sufficiently large enough to enable fault currents to be deflected during fault conditions.

According to a second advantageous embodiment of the device according to the invention, the rods or the pipes are placed so close together in the end winding region that electric arcs in the event of an internal fault are safely directed to ground, i.e. an arc occurring in the event of an internal fault is safely caught by the fault-current control device before it finds its way to other cables or the stator lamination.

According to yet another advantageous embodiment of the device according to the invention, the rods or the pipes are inserted a certain distance into the end winding region, this distance being limited so that eddy currents produced in the rods or the pipes are below a predetermined magnitude.

According to still another advantageous embodiment of the device according to the invention, the rods or the pipes are slotted in order to reduce eddy-current losses.

According to yet another advantageous embodiment of the device according to the invention, the rods or the pipes comprise a plurality of rods or pipes of small diameter combined to a bundle having sufficient cross-sectional area to deflect short-circuiting currents arising in the end winding region in the event of a fault.

According to still another advantageous embodiment of the device according to the invention, the rods or the pipes are arranged to be in contact with spacers made of resilient, electrically conducting material, said spacers being applied between adjacent winding cables in the end winding region, in contact with the semi-conducting layers of the winding cables. The rods or the pipes may hereby be inserted into the spacers or into lugs provided on the spacers and each rod or pipe may be arranged to be in contact with several spacers arranged one after the other in the direction of the stator end. In this way the cables in the end winding region part are grounded via the fault-current control rods or pipes which are designed to be able to deflect considerable fault currents.

According to yet another advantageous embodiment of the device according to the invention, the rods, pipes or the like are also used to mechanically stabilize the end winding.

With the device according to the invention, an arc due to an internal fault in the end winding region will be directed to ground via a fault-current control device. The damage to the end winding region is thus reduced.

Embodiments of the invention will now be described in more detail by way of examples only, with particular reference to the accompanying drawings in which;

Figure 1 shows a part of the stator, partially cut away and with the rotor removed,

Figure 2 shows a part of the end winding region with rods inserted for fault current control,

Figure 3 shows a part of the end winding region seen from "inside" the end winding , with spacers between the cables grounded by means of the fault-current control rods,

Figures 4 and 5 shows a detail of the end winding region in Figure 3 on a larger scale.

Figure 6 shows the arrangement in Figures 4 and 5 grounded through a fault-current control rod, and

Figures 7, 8 and 9 are views corresponding to Figures 4, 5 and 6, respectively, showing an alternative embodiment of the spacers between the cables.

Figure 1 thus shows a part of the stator 2 in a rotating high-voltage electric machine. The stator 2 is partially cut away and the rotor removed for greater clarity. The stator winding cables are placed in radial slots 8 in the stator core. The slots 8 extend to the rear section 4 of the stator core.

Figure 2 shows a part of the upper end winding region of the stator as shown in Figure 1 with fault-current control rods inserted between the cables 12 in the end

winding region. The fault-current control rods 10 in the figure, are inserted from above, ending a certain distance from the lamination upper surface 13.

The rods 10 are grounded and the conductors 14 are designed to connect several rods, at 16 ... 18, to a group of rods 10. The rods 10 are placed so close together in the end winding that an arc in is safely directed to ground via the rods 10 and conductor 14 without finding its way to other cables 12 or to the stator lamination, which would otherwise be damaged. The conductor 14 is preferably made of copper or aluminium.

Each fault-current control rod 10 suitably comprises a plurality of rods of small diameter, e.g. 3 mm, combined in to a bundle of rods having sufficient cross-sectional area, e.g. 100 mm^2, to deflect short-circuit currents appearing in the end winding region in the event of a fault. The eddy-current losses are thus reduced.

Figure 3 shows a part of the end winding region from "inside" the end winding, with spacers 20 arranged between adjacent cables 12. The arrangement of these spacers 20, known from patent application entitled "Device at the end winding region in a rotating electric machine", is shown in more detail in Figures 4 and 5. Adjacent cables 12 are thus clamped together (not shown in detail in the figures) with an intermediate spacer 20 of a resilient, electrically conducting material.

The cables 12 consist of a conducting core 22, surrounded by a semi-conducting layer 24, a solid insulation 26 and an outer semi-conducting layer 28 in contact with the spacers 20, as can be seen in Figure 4. The outer semi-conducting layers 28 of the cables 12 are thus electrically connected to each other through intermediate spacers 20. A protruding lug 30 with a hole 32 running through it, is provided at the side of the spacers 20. A fault-current control rod 10 is inserted through the hole 32 in the lug 30 and connected to ground via the conductor 14, see Figures 3 and 6. The semi-conducting outer layers 28 of the cables 12 are therefore grounded via spacers 20, fault-current control rods 10 and the ground conductor 14. As can be seen in Figures 3 and 6, each conductor 14 is connected to a plurality of fault-current control rods, illustrated at 16...18 in a group of rods.

Figures 7, 8 and 9 show views corresponding to those in Figures 4, 5 and 6, respectively, of an alternative embodiment of the spacer 34 with an elongated lug

or flange 36 which, unlike the lug 30 in Figures 4-6, extends along the entire length of the spacer 34. A hole 38 runs through this flange 36, in which a fault-current control rod 10 is inserted via the conductor 14 which combines several fault-current control rods, at 16...18, in to a group of rods, connected to ground.

The ground potential is normally defined by the outer casing of the machine.

AMENDED CLAIMS

1. A rotating electric machine for high voltage comprising a stator (2), a rotor and windings, characterized in that the windings comprise high voltage cables enclosing the electric field within the windings and in that a device (10) for fault current control is provided comprising a rod, pipe or the like of an electrically conducting material connected to ground and arranged in the end winding region.

2. A rotating electrical machine as claimed in claim 1, characterized in that an arrangement of rods, pipes or the like in the end winding region is placed so that the largest physical distance between the rods, pipes or the like is small enough to ensure a deflection of an arc in the end winding region to ground.

3. A rotating electrical machine as claimed in claim 1 or claim 2, characterized in that the rods, pipes or the like are inserted a specific distance into the end winding region and this distance being limited, so that eddy currents produced in the rods, pipes or the like are below a predetermined magnitude.

4. A rotating electrical machine as claimed in any of claims 1-3, characterized in that the rods, pipes or the like are slotted in order to reduce eddy-current losses.

5. A rotating electrical machine as claimed in any of claims 1-3, characterized in that the rods, pipes or the like comprises a plurality of small conductors combined in to a bundle having sufficient cross-sectional area to deflect short-circuit currents arising in the end winding region in the event of a fault.

6. A rotating electrical machine as claimed in any of claims 1-5, characterized in that the rods, pipes or the like are arranged to be in contact with spacers of resilient, electrically conducting material, said spacers being applied between adjacent cables in the end winding region and in contact with the outer semi-conducting layers of the cables.

7. A rotating electrical machine as claimed in claim 6, characterized in that the rods, pipes or the like are inserted into the spacers.

8. A rotating electrical machine as claimed in any of claims 6-7, characterized in that the rods, pipes or the like are arranged in contact with several spacers arranged one after the other in the direction of the end of the stator.

9. A rotating electrical machine as claimed in any of claims 1-8, characterized in that the device consist of a flexible wire.

10. A rotating electrical machine as claimed in any of claims 1-9, characterized in that the device also is used to mechanically stabilize the end winding.

11. A rotating electric machine as claimed in any of the claims 1-10, characterized in that the high voltage cable is flexible and comprises one or more current-carrying conductor, wherein around each conductor there is arranged an inner layer with semiconducting properties and around the inner layer there is arranged a solid insulating part and around the insulating part there is arranged an outer layer with semiconducting properties.

12. A rotating electric machine as claimed in any of the claims 1-11, characterized in that the winding thereof is designed for a voltage suitably in excess of 36 kV, and preferably up to very high voltages, such as 400 kV to 800 kV.

Fig. 1

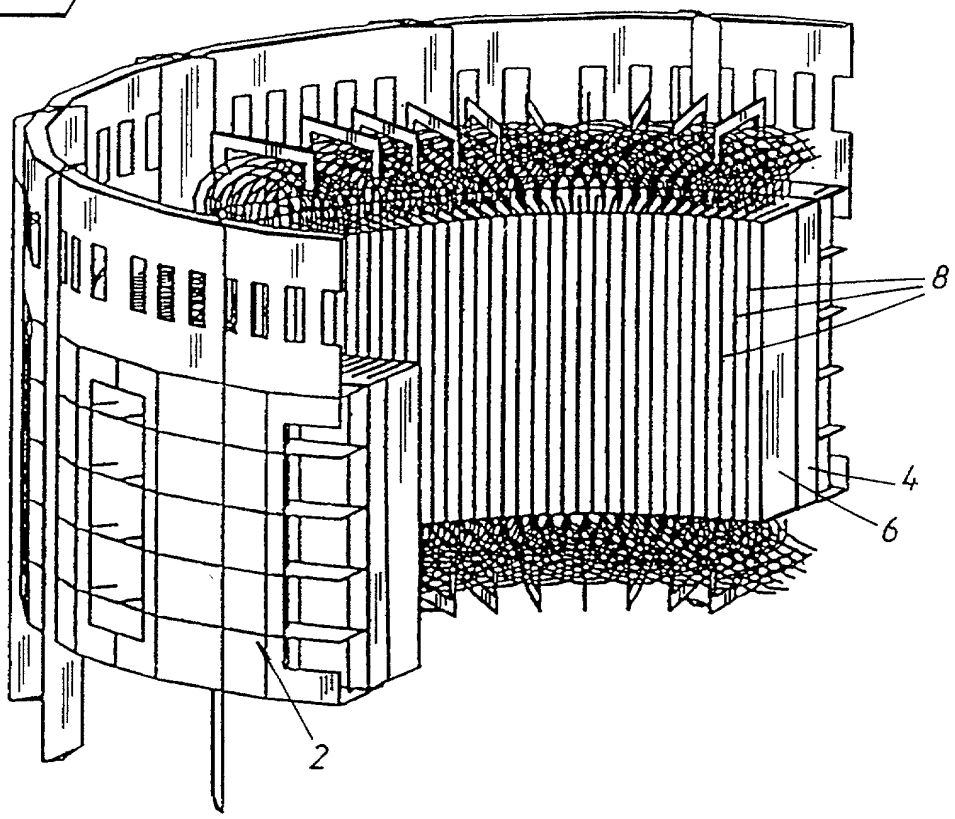


Fig. 2

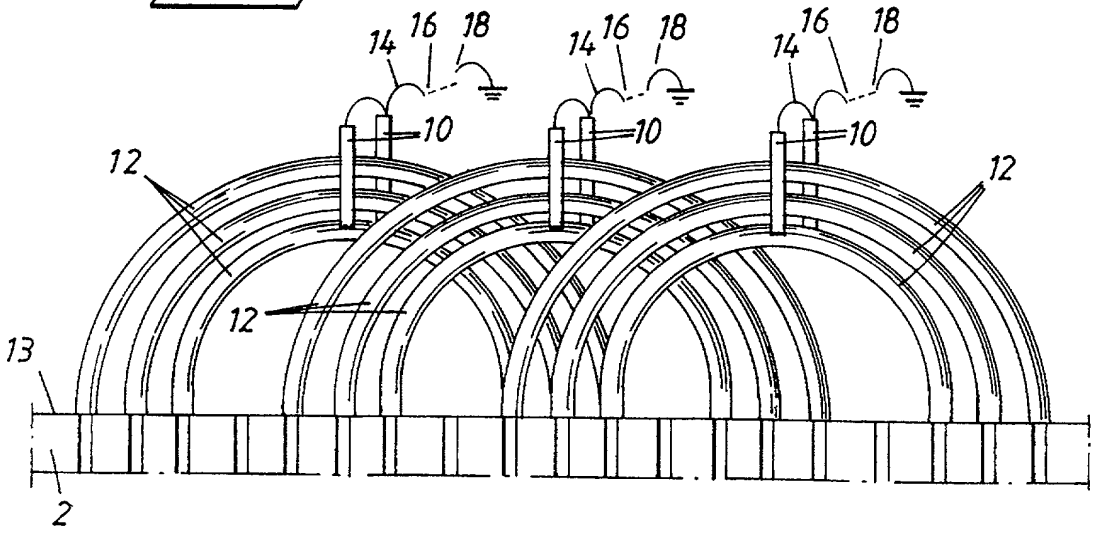


Fig. 3

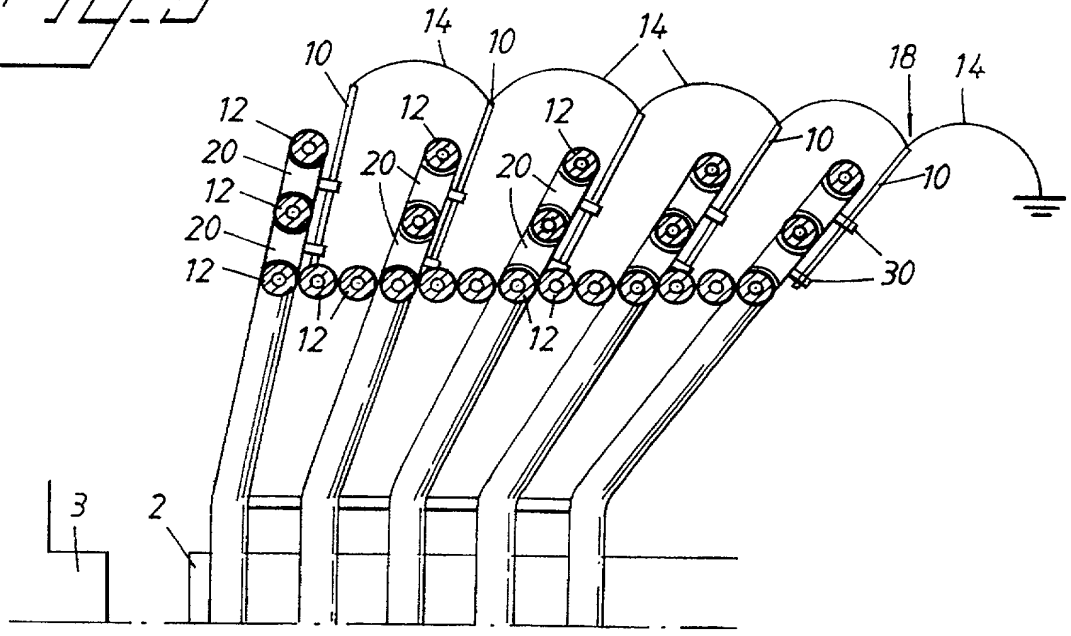


Fig. 4

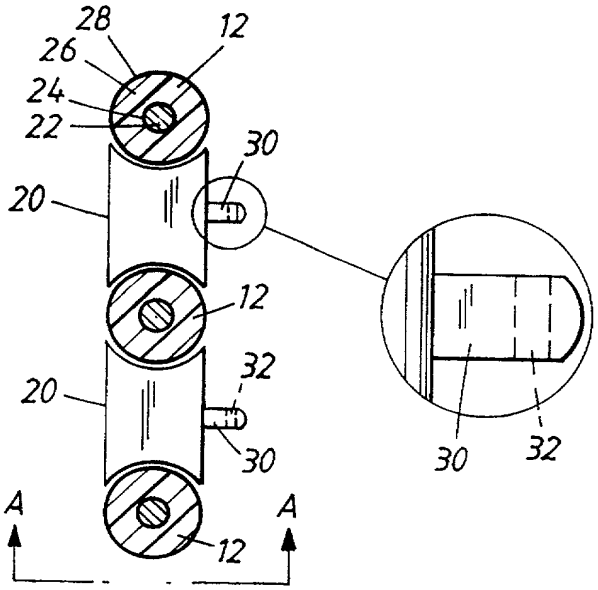


Fig. 5

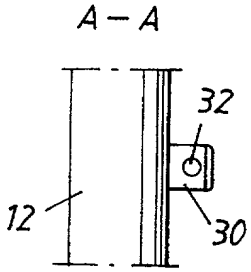


Fig. 6

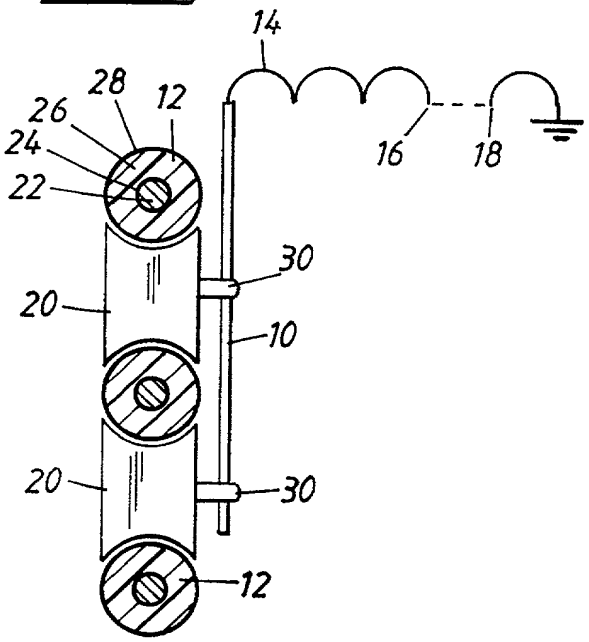


Fig. 7

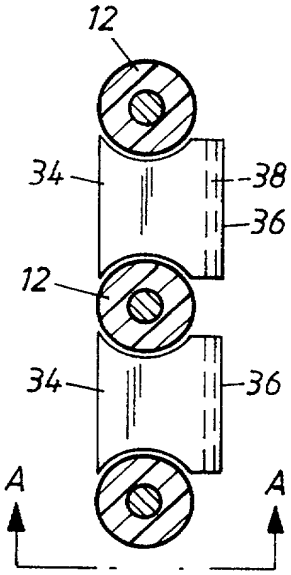


Fig. 8

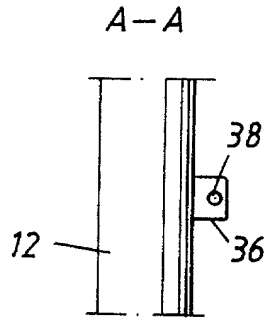
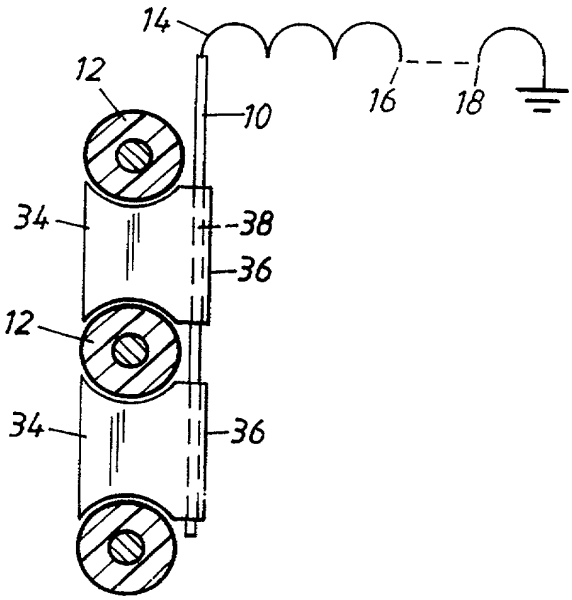


Fig. 9



Declaration, Power Of Attorney and Petition

WE (I) the undersigned inventor(s), hereby declare(s) that:

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

DEVICE FOR CONTROLLING FAULT CURRENTS IN A ROTATING ELECTRIC MACHINE

the specification of which

☐ is attached hereto.

☒ was filed on MAY 4, 1999 as

Application Serial No. _____

and amended on _____.

☒ was filed as PCT international application

Number PCT/SE97/01844

on NOVEMBER 4, 1997,

and was amended under PCT Article 19

on _____ (if applicable).

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application(s)

Application No.	Country	Day/Month/Year	Priority Claimed
9604034-0	SWEDEN	4 NOVEMBER 1996	☒ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No

We (I) hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

(Application Number) (Filing Date)

(Application Number) (Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

Application Serial No.	Filing Date	Status (pending, patented, abandoned)
PCT/SE97/01844	4 NOVEMBER 1997	

And we (I) hereby appoint: Norman F. Oblon, Reg. No. 24,618; Marvin J. Spivak, Reg. No. 24,913; C. Irvin McClelland, Reg. No. 21,124; Gregory J. Maier, Reg. No. 25,599; Arthur I. Neustadt, Reg. No. 24,854; Richard D. Kelly, Reg. No. 27,757; James D. Hamilton, Reg. No. 28,421; Eckhard H. Kuesters, Reg. No. 28,870; Robert T. Pous, Reg. No. 29,099; Charles L. Gholz, Reg. No. 26,395; Vincent J. Sunderdick, Reg. No. 29,004; William E. Beaumont, Reg. No. 30,996; Robert F. Gnuse, Reg. No. 27,295; Jean-Paul Lavalleye, Reg. No. 31,451; Stephen G. Baxter, Reg. No. 32,884; Martin M. Zoltick, Reg. No. 35,745; Robert W. Hahl, Reg. No. 33,893; Richard L. Treanor, Reg. No. 36,379; Steven P. Weihrouch, Reg. No. 32,829; John T. Goolkasian, Reg. No. 26,142; Richard L. Chinn, Reg. No. 34,305; Steven E. Lipman, Reg. No. 30,011; Carl E. Schlier, Reg. No. 34,426; James J. Kulbaski, Reg. No. 34,648; Richard A. Neifeld, Reg. No. 35,299; J. Derek Mason, Reg. No. 35,270; Surinder Sachar, Reg. No. 34,423; Christina M. Gadiano, Reg. No. 37,628; Jeffrey B. McIntyre, Reg. No. 36,867; and Paul E. Rauch, Reg. No. 38,591; our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of OBLON, SPIVAK, McCLELLAND, MAIER & NEUSTADT, P.C., whose Post Office Address is: Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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